

2019 EUVL Workshop

June 10-13, 2019

CXRO, LBL ▪ Berkeley, CA

Workshop Proceedings



2019 EUVL Workshop Sponsors



Organized by



Vivek Bakshi (EUV Litho, Inc.), Chair

Patrick Naulleau (CXRO), Co-Chair

Workshop Proceedings

2019 EUVL Workshop

*CXRO, LBL, Berkeley, CA, USA
June 10-13, 2019*

Workshop Proceedings

Tuesday, June 11, 2019

CXRO EUVL Program Showcase: 11:30 AM to 4:30 PM

Presentations on Technology, facilities, services and research from CXRO, LBL

Building name: Building 54 (Also known as Bay View Cafeteria – name not shown on the building)

Room Number: 130

SESSION 1 – Recent Progress by the CXRO Team

Session Chair: Patrick Naulleau

11:30 AM – 11:45 AM [Introductory Remarks \(Patrick Naulleau\)](#)

11:45 PM – 01:00 PM Networking Lunch

01:00 PM – 03:10 PM Presentations

[Achieving Diffraction-limited Performance on the Berkeley MET5 \(P61\)](#)

Ryan Miyakawa
CXRO

[A SHARP tool for current and future nodes of EUV lithography \(P62\)](#)

Markus Benk, Ryan Miyakawa, Patrick Naulleau
CXRO

[Measuring chemical image in photoresist \(P63\)](#)

Luke Long
CXRO

[Quantitative Phase Imaging for EUV Photomasks \(P64\)](#)

Stuart Sherwin
CXRO

Photoemission study on EUV materials (P65)

Jonathan Ma, Andrew Neureuther, Patrick Naulleau
CXRO

2:40 pm – 3:10 pm COFFEE BREAK

SESSION 2 – Facilities and Research at LBNL

Session Chair: Isvar Cordova

3:10 – 4:30 PM Presentations

Measurement of electron blur (P66)

Oleg Kostko, Jonathan Ma, and Patrick Naulleau
Chemical Sciences/Advanced Light Source, LBL

Assessing the Impact of Latent Imaging of Resists via Grazing Incidence Resonant X-ray Scattering (P67)

Isvar. A. Cordova^{1,2}, Guillaume. Freychet^{1,4}, Scott. D. Dhuey³, Alex Hexemer¹, Cheng Wang¹, Patrick Naulleau³

¹Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA

²Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA

³Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA

⁴NSLS-II, Brookhaven National Laboratory, Berkeley, CA 94720 USA

Gentle High Speed Atomic Force Microscopy using Encased Cantilevers and Spiral Scanning (P68)

Paul Ashby
Molecular Foundry

Fundamental dynamics of bond-selective chemistry initiated by low-energy electrons (P69)

Dan Slaughter¹, Ali Belkacem¹ and Tom Rescigno¹, Cynthia Trevisan², C. William McCurdy³

¹Chemical Sciences Division, LBNL

²Department of Sciences and Mathematics, California Maritime Academy

³Chemical Sciences Division, LBNL, and Department of Chemistry, University of California

Wednesday, June 12, 2019

8:30 AM Welcome and Introduction

Welcome to 2019 EUVL Workshop (Intro-1A)

Vivek Bakshi, *EUV Litho, Inc.*

Welcome to LBL

Mark Asta, Material Science Division, *LBL*

Announcements (Intro-1B)

Patrick Naulleau, *LBL*

Introductions

All

Session 1: Keynote – 1

Session Chair: Patrick Naulleau (LBL)

**[Canonical Phase Measurement in Quantum Mechanics \(P1\)](#)
(Keynote Presentation)**

Irfan Siddiqi

University of California Berkeley and Lawrence Berkeley National Lab

**[EUV lithography Today and Extension for the Next Generation \(P2\)](#)
(Keynote Presentation)**

Britt Turkot

Intel Corporation

10:40 AM Break (20 minutes)

Session 2: EUV Masks

Session Co-chairs: Jane P. Chang (UCLA) and Jinho Ahn (Hanyang)

[Ion Beam Technology Roadmap for EUV Mask Deposition and Absorber Etch Processes \(Invited\) \(P14\)](#)

Sandeep Kohli, Meng Lee, Boris Druz, Adrian Devasahayam

Veeco Instruments, 1 Terminal Drive, Plainview, NY 11803

[Next Generation EUV Mask Blank Absorber Development \(Invited\) \(P16\)](#)

Vibhu Jindal, Shuwei Liu, Kan Fu, Weimin Li, Wen Xiao, Khor Wui,

Madhavi Chandrathood

Applied Materials

Selective and Directional Patterning of Ni for EUV Masks Application (Invited) (P11)

Jane P. Chang

Department of Chemical and Biomolecular Engineering, University of California, Los Angeles (UCLA), Los Angeles, CA 90095

Fabrication and Evaluation of SiN-based EUV Pellicle (Invited) (P12)

Ha Neul Kim¹, Yong Ju Jang², Seong Ju Wi¹, Juhee Hong³, Chang Hoon Lee³, Kee Soo Nam³ and Jinho Ahn^{1,2}

¹*Division of Materials Science and Engineering*

²*Division of Nanoscale Semiconductor Engineering*

Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, Republic of Korea

³*S&S tech Co. Ltd., 42, Hosandong-ro, Dalseo-gu, Daegu, Republic of Korea*

Stochastic Failure Risk (Invited) (P13)

Kevin Lucas

Synopsys, Austin, TX

Stochastic Investigation of the Impact of Absorber Variations on Wafer Patterns (Invited) (P15)

Derren Dunn¹, Lawrence S. Melvin III², Tim Fühner²

¹*IBM Research, 257 Fuller Rd, Albany, NY 12203, USA*

²*Synopsys, Inc. 2025 NW Cornelius Pass Road, Hillsboro, OR 97124, USA*

Lunch 1:00 PM – 2:00 PM

Session 3: EUV Resist

Session Co-chairs: Anna Lio (Intel Corporation) and Alex Robinson (Irresistible Materials)

EUV Resists: Can We Move Fast and Light? (Invited) (P34)

Anna Lio

Intel Corporation

Multi-Trigger Resist (Invited) (P33)

G. O'Callaghan^{a,b}, C. Popescu^b, Y. Vesters^{c,d}, A. McClelland^b, J. Roth^e, W. Theis^f, A.P.G. Robinson^{a,b}

^a*Irresistible Materials, Birmingham Research Park, Birmingham, UK*

^b*School of Chemical Engineering, University of Birmingham, UK.*

^c*IMEC, Kapeldreef 75, 3001 Leuven, BE*

^d*KU Leuven, Chemistry Department, Celestijnenlaan 200F, 3001 Leuven, BE*

^e*Nano-C, 33 Southwest Park, Westwood, MA, USA.*

^f*School of Physics and Astronomy, University of Birmingham, UK.*

Role of Ambient Conditions on Organotin Cluster Based Extreme Ultraviolet Resist Chemistries (P35)

Gregory S. Herman, J. Trey Diulus, Ryan T. Frederick, Rafik Addou
*School of Chemical, Biological, and Environmental Engineering, Oregon State University,
Corvallis, OR, 97331, USA*

Break and Group Photograph 3:00 PM (30 Minutes)

Session 4: EUV Optics and Patterning

Session Chair: Sascha Migura (Carl Zeiss) and Ladislav Pina (CTU)

Optics for EUV Lithography (Invited) (P24)

Sascha Migura
Carl Zeiss SMT GmbH, Germany

Defectivity Improvements Enabling HVM for EUV Scanners (P23)

Mark van de Kerkhof, Christian Cloin, Andrei Yakunin, Ferdi van de Wetering,
Andrey Nikipelov, Fabio Sbrizzai
ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands

Update on EUV Optics Calibration (P21)

Eric Gullikson
CXRO

Maskless, High-NA EUV Scanner (P22)

Kenneth C. Johnson
KJ Innovation, 2502 Robertson Rd., Santa Clara, CA 95051

Overview, Status and Performance of the 0.5-NA EUV Microfield Exposure Tool at Berkeley Lab (P25)

Chris Anderson
Berkeley Lab, 1 Cyclotron Road Mail Stop 2R0400, Berkeley, CA 94720 USA

Break: 5:10 PM

Session 5: Poster Session 5:30 6:30 PM

Assessing the Impact of Latent Imaging of Resists via Grazing Incidence Resonant X-ray Scattering (P31)

Isvar. A. Cordova^{1,2}, Guillaume Freychet^{1,4}, Scott. D. Dhuey³, Alex Hexemer¹, Cheng Wang¹, Patrick Naulleau³

¹Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA

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³Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA

⁴NSLS-II, Brookhaven National Laboratory, Berkeley, CA 94720 USA

SECOND PLACE – BEST POSTER AWARDS

Progress in EUV Resists Towards High-NA EUV Lithography (P32)

Xiaolong Wang¹, Zuhail Tasdemir¹, Michaela Vockenhuber¹, Iacopo Mochi¹, Lidia van Lent-Protasova², Marieke Meeuwissen², Rolf Custers², Gijsbert Rispens², Rik Hoefnagels², Yasin Ekinci¹

¹Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland

²ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands

THIRD PLACE – BEST POSTER AWARDS

Development of EUV-ptychography Microscope: EUV Scanning Lensless Imaging (ESLI) (P17)

Dong Gon Woo¹, Young Woong Kim¹, Yong Ju Jang², Seong Ju Wi¹, Seung Hyuk Shin³, Whoi-Yul Kim³ and Jinho Ahn^{1,2}

¹ Division of Materials Science and Engineering

² Division of Nanoscale Semiconductor Engineering

³ Department of Electronics and Computer Engineering

Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea

Study of the Reflection-field Features of EUV Mask Blank with Defects in Multilayers (P18)

Guannan Li^{1,2}, Lituo Liu¹, Weihu Zhou¹, Xiaobin Wu¹, Xiaomei Chen¹, Yu Wang¹, Dongbin Mei¹

¹Institute of Micro-electronics of the Chinese Academy of Sciences, Beijing 100029, China

²University of Chinese Academy of Sciences, Beijing 100049, China

Thermo-mechanical Characteristics of EUV Pellicle with Particle Contamination (P19)

Ha Neul Kim¹, Yong Ju Jang², Seong Ju Wi¹, and Jinho Ahn^{1, 2}

¹Division of Materials Science and Engineering

²Division of Nanoscale Semiconductor Engineering

Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, Republic of Korea

Study of Feature Extraction and Classification of Defects from EUV Mask with Arbitrary Pattern Using Convolutional Neural Network (P20)

Lituo Liu¹, Guannan Li^{1,2}, Weihu Zhou¹, Xiaobin Wu¹, Dongbin Mei¹, Yu Wang¹

¹*Institute of Micro-electronics, Chinese Academy of Science, Beijing, 100029, China*

²*University of Chinese Academy of Sciences, Beijing, 100049, China*

FIRST PLACE – BEST POSTER AWARDS

Adaptive piezoelectric optics for XUV wavelengths (P26)

Muharrem Bayraktar¹, Mohammadreza Nematollahi¹, Philip Lucke¹, Andrey Yakshin¹, Eric Louis¹, Guus Rijnders² and Fred Bijkerk¹

¹*Industrial Focus Group XUV Optics, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands*

²*Inorganic Materials Science Group, MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands*

Measuring chemical image in photoresist (P63)

Luke Long

CXRO

Quantitative Phase Imaging for EUV Photomasks (P64)

Stuart Sherwin

CXRO

Photoemission study on EUV materials (P65)

Jonathan Ma, Andrew Neureuther, Patrick Naulleau

CXRO

Alkyltin Keggin clusters as photoresist material for EUV lithography (P70)

Rebecca Stern

UC-Berkeley

Sponsor's Commercial Poster (P46B)

Sam Gunnel

Energetiq

End Day 1

Thursday, June 13, 2019

8:30 AM Announcements (Intro-2)
Patrick Naulleau, LBL

Session 6: Keynote-2

Session Chair: Eric Panning (Intel)

[EUV Lithography Research and Development Activities in Japan \(Keynote Presentation\) \(P4\)](#)

Takeo Watanabe
University of Hyogo

[Enabling the Semiconductor Roadmap from a Multi-Angled Approach \(Keynote Presentation\) \(P3\)](#)

Steven Welch
Applied Materials

Session 7: EUV Sources

Session Co-Chairs: Hakaru Mizoguchi (Gigaphoton) and Fariba Abhari (Adlyte Corporation)

[Challenge of High Power LPP-EUV Source with Long Collector Mirror Lifetime for Semiconductor HVM \(Invited\) \(P44\)](#)

Hakaru Mizoguchi, Hiroaki Nakarai, Tamotsu Abe, Hiroshi Tanaka, Yukio Watanabe, Tsukasa Hori, Yutaka Shiraishi, Tatsuya Yanagida, Georg Soumagne, Tsuyoshi Yamada and Takashi Saitou
Gigaphoton Inc. Hiratsuka facility, 3-25-1 Shinomiya Hiratsuka Kanagawa, 254-8567, JAPAN

[Lithography Machine In-line Broadband Spectrum Metrology and Feedback-control System \(P43\)](#)

Fei Liu¹, Dries Smeets¹, Sjoerd Huang¹, Andrei Yakunin¹, Peter Havermans¹, Rene Oosterholt¹, Muharrem Bayraktar², Fred Bijkerk²

¹ASML Netherlands B.V., De Run 6501, 5504 DR Veldhoven, The Netherlands

² Industrial Focus Group XUV Optics, MESA + Institute for Nanotechnology, University of Twente, The Netherlands

[Energetiq Source Update \(Invited\) \(P46\)](#)

Toru Fujinami
Energetiq

[Adlyte Corporation – Source Update \(Invited\) \(P42\)](#)

Fariba Abhari
Adlyte Corporation, Switzerland

[EUV Metrology with a Compact Accelerator-based Source \(Invited\) \(P41\)](#)

Yasin Ekinici
Paul Scherrer Institut, Switzerland

[High Repetition Rate \(81.25MHz\) FEL Project Based on cERL \(P45\)](#)

Hiroshi Kawata, Hiroshi Sakai, Norio Nakamura, and Ryukou Kato
High Energy Accelerator Research organization (KEK)

Lunch 12:20 PM (80 Minutes)

Steering Committee working lunch meeting (Closed meeting)

Session 8: Blue-X I

Session Co-Chairs: Craig Siders (LLNL) and Tatyana Sizyuk (Purdue University)

[Blue-X: the New Frontier \(P58\)](#)

Vivek Bakshi
EUV Litho, Inc.

[Thulium-based EUV Drive Lasers Scalable to Near-MW Average Powers \(Invited\) \(P51\)](#)

C. W. Siders, S. Langer, A.C. Erlandson, T.C. Galvin, B.A. Reagan, E.F. Sistrunk, T.M. Spinka, and C. L. Haefner
Advanced Photon Technologies, Lawrence Livermore National Laboratory, NIF & Photon Science Directorate, 7000 East Avenue, Livermore CA 94550

[An Optimization Study of EUV Sources driven by Lasers of Different Wavelengths \(Invited\) \(P53\)](#)

Steven Langer, Howard Scott, and Craig Siders
Lawrence Livermore National Laboratory

[Effect of Laser Wavelength on EUV Plasma Dynamics, Source Efficiency, and Ionic Debris Evolution \(Invited\) \(P56\)](#)

Tatyana Sizyuk
*Center for Materials under Extreme Environment (CMUXE)
College of Engineering, Purdue University, West Lafayette, IN, 47907*

Break 2:50 PM (20 Minutes)

Session 9: Blue-X II

Session Co-chairs: Regina Soufli (LLNL) and Frank Delmotte (Universite Paris-Saclay)

Advanced Multilayer Development for the Water-Window Spectral Region (Invited) (P52)

F. Delmotte, C. Burcklen**, E. Meltchakov, J. Rebellato, S. de Rossi
Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Universite Paris-Saclay, 91127 Palaiseau Cedex, France

*** current affiliation: Lawrence Livermore National Laboratory, Livermore, California, USA*

Refractive index measurements with improved accuracy around EUV/x-ray absorption edges and impact in multilayer modeling (Invited) (P54)

Regina Soufli¹, Franck Delmotte², Farhad Salmassi³, Julia Meyer-Ilse³, Catherine Burcklen¹, Jennifer Rebellato², Nicolai Brejnholt¹, Sonny Massahi⁴, David Girou⁴, Finn Christensen⁴, Eric M. Gullikson³

¹*Lawrence Livermore National Laboratory, Livermore, California*

²*Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, Palaiseau, France*

³*Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, California*

⁴*Danish Technical University (DTU)-Space, Lyngby, Denmark*

Adaptation of the Reflectance of Bragg Mirrors to Wide Source Spectra (Invited) (P57)

R. Meisels and F. Kuchar

Institute of Physics, Montanuniversitaet, 8700 Leoben, Austria

Characterization of laser-produced plasmas in the 1-6 nm region using cryogenic Xe targets (P55)

S. C. Bott-Suzuki¹, A. Bykanov², O. Khodykin², M. Tillack¹, S. Cordaro¹

¹*University of California San Diego, 9500 Gilman Drive #0417, La Jolla, CA 92093-0417, USA*

²*KLA-Tencor Corporation, Milipitas, CA, USA*

Announcements

Vivek Bakshi

EUV Litho, Inc.

Workshop Summary

Vivek Bakshi

EUV Litho, Inc.

